1-1-1992

Fidelity Description Requirements For Distributed Interactive Simulation: IEEE Standard

University of Central Florida Institute for Simulation and Training

INSTITUTE FOR SIMULATION AND TRAINING

FIDELITY DESCRIPTION REQUIREMENTS FOR DISTRIBUTED INTERACTIVE SIMULATION

DECEMBER 31, 1992

IST DOCUMENTATION

METRIC

WORKING DRAFT STANDARD
31 December 1992

IEEE STANDARD

FIDELITY DESCRIPTION REQUIREMENTS

FOR DISTRIBUTED INTERACTIVE SIMULATION

"NOTE: This working draft, dated 31 December 1992, prepared by the Institute for Simulation and Training for STRICOM, has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL. (Project _______)"

CONTENTS

PARAGRAPH *PAGE*

PARAGRAPH *PAGE*

PARAGRAPH *PAGE*

LIST OF FIGURES AND TABLES

1.0 SCOPE

1.1 Scope. This standard establishes the Fidelity Correlation Requirements for simulators participating in a distributed interactive simulation. It is one of a series of standards being developed to address the problem of interoperability among interconnected simulators.

1.2 Application. When invoked in a specification or statement of work, these requirements will apply to simulation devices intended for participation in a Distributed Interactive Simulation (DIS). The contractor is responsible for invoking all the applicable requirements of this Military Standard on any and all subcontractors that may be employed.

2.0 APPLICABLE DOCUMENTS

2.1 Government documents

2.1.1 Specifications, standards, and handbooks

2.2 Non-Government publications

GENERAL INFORMATION

Distributed Interactive Simulation: Operational Concept (Draft 2.0). Orlando, FL: Institute for Simulation and Training

INTEROPERABILITY MEETINGS

IST-CF-89-1 -	Summary Report: The First Conference on Standards for the Interoperability of Defense Simulations
IST-CF-90-01-	Summary Report: The Second Conference on Standards for the Interoperability of Defense Simulations
IST-CR-90-13-	Summary Report: The Third Workshop on Standards for the Interoperability of Defense Simulations
IST-CR-91-11-	Summary Report: The Fourth Workshop on Standards for the Interoperability of Defense Simulations
IST-CR-91-13-	Summary Report: The Fifth Workshop on Standards for the Interoperability of Defense Simulations
IST-CR-92-2-	Summary Report: The Sixth Workshop on Standards for the Interoperability of Defense Simulations
IST-CR-92-17.1, IST-CR-92-17.2	Summary Reports: The Seventh Workshop on Standards for the Interoperability of Defense Simulations (Volumes I and II)

DRAFT STANDARDS

IEEE P1278	IEEE Standard for Information Technology, Application Protocol for Distributed Interactive Simulation
IST-CR-92-6	Draft Military Standard: Communication Architecture for Distributed Interactive Simulation
IST-CR-92-8	Draft Military Standard: Fidelity Description Requirements

ACCOMPANYING DOCUMENTS

IST-CR-92-11	Rationale Document for Exercise Control and Feedback Requirements for Distributed Interactive Simulation **(DRAFT)**
IST-CR-92-12	Rationale Document for Fidelity Description Requirements for Distributed Interactive Simulation **(DRAFT)**
	Distributed Interactive Simulation Glossary Update (22 September 1992). Loral ADST Program Office.

3.0 DEFINITIONS

entity - Any vehicle, craft, weapon system, or physical object, manned or computer-generated, that is part of a DIS exercise. This vehicle, craft, weapon system, or physical object can assume either a passive or active role in a given exercise.

simulation fidelity - Refers to the degree of similarity between the training situation and the operational situation that is being simulated.

unit - An aggregation of entities.

Battlespace Entity ? (Refer to ADST Glossary)
Environment Entity ?
Fidelity ?
Manned Platform Entity ?

4.0 GENERAL REQUIREMENTS

4.1 Introduction. This section contains Fidelity Description Requirements for DIS.

4.2 Purpose. This standard provides mechanisms and guidelines required to measure the relative functionality and fidelity of dissimilar DIS participants.

4.3 Use. This standard does not dictate who can or cannot participate in a DIS exercise. This responsibility is in the hands of the activity organizing the DIS exercise, and will be based on the analyses of comparative data required or recommended by this standard.

5.0 DETAILED REQUIREMENTS

Figure 1 contains a taxonomy of the Fidelity Description Requirements.

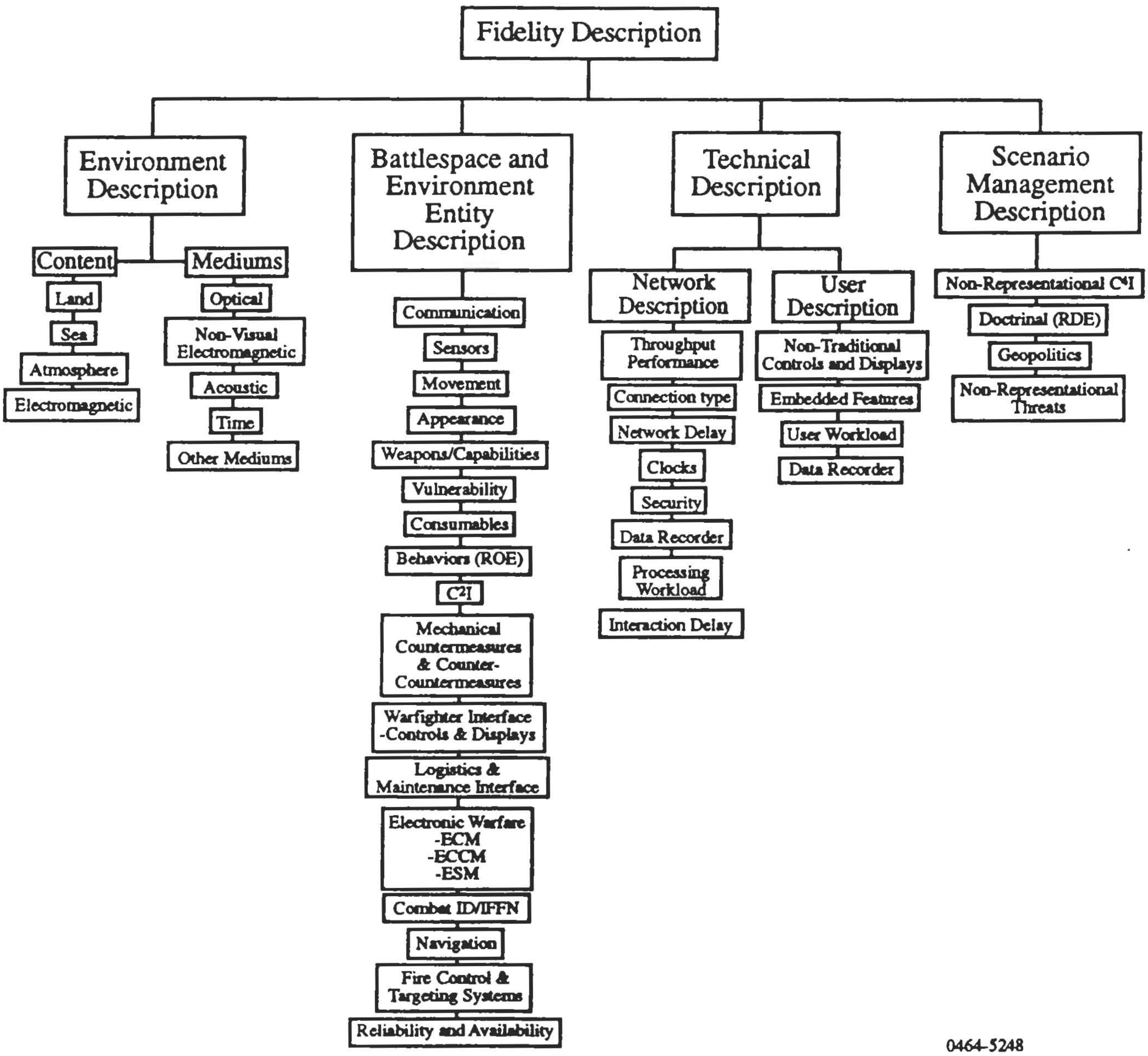

Figure 1. Fidelity Description Taxonomy

5.1 Environment Modeling

5.1.1 Content (TBD)

5.1.1.1 Land (TBD)
5.1.1.2 Sea (TBD)
5.1.1.3 Atmosphere (TBD)
5.1.1.4 Electromagnetic (TND)

5.1.2 Mediums (TBD)

5.1.2.1 Optical (TBD)

5.1.2.1.1 Line-of-Sight Intervisibility Requirements (TBD)

In order to (1) promote positive training transfer from DIS engagements to real world engagements, and (2) promote valid evaluations of developmental materiel, the terrain and features data bases in all DIS exercise participants shall have a correlation coefficient no lower than the values specified in Table 1. These correlation coefficients shall be calculated based on the technique specified in Appendix D.

Table 1
Minimum Line-of-Sight Intervisibility Requirements
Between Terrain/Feature Data Bases

	TARGET TYPE			
VIEW TYPE	DI	TANK	ROTARY	FIXED
DI	XX	XX	XX	XX
TANK	XX	XX	XX	XX
ROTARY	XX	XX	XX	XX
FIXED	XX	XX	XX	XX

5.1.2.1.2 Target/Background Contrast Ratio Requirements

In order to provide realistic training exercises and valid developmental equipment evaluation tests, the target/background contrast ratio should be approximately the same on all simulators. In order to promote the achievement of this goal, the target/background contrast ratio for selected targets in DIS exercises shall be as specified in Table 2. The values in

Table 2 were derived from an independent survey of image generator manufacturers whose equipment is DIS-compatible. All measures were taken off direct view CRTs. The specified white object color stimulus used in the ΔE^*_{uv} calculation (see Appendix A) was the maximum white stimulus that an image generator/monitor combination could display.

These values shall be calculated as specified in Appendix A - Target/Background Contrast Ratio Metric: Calculation of ΔE^*_{uv} . The ΔE^*_{uv} values in Table 2 have been rounded to the nearest whole number. Appendices B and C reflect the mean chromaticity and luminance values across all targets and backgrounds, respectively. These values are used as part of the ΔE^*_{uv} calculation (refer to Appendix A).

Table 2. Recommended ΔE^*_{uv} values and ranges for target/background combination.

Target	Background	Recommended ΔE^*_{uv}	Recommended Range
Green Monochrome Surface Vehicle	Sky	82	77-87
Green Monochrome Surface Vehicle	Cloud	69	64-74
Green Monochrome Surface Vehicle	Tree Line	31	26-36
Green Monochrome Surface Vehicle	Grass	28	23-33
Green Monochrome Surface Vehicle	Earth	29	24-34
Green Camouflage [1] Surface Vehicle			
	Sky	62	57-67
	Cloud	65	60-70
Green	Tree Line	14	9-19
	Grass	16	11-21
	Earth	12	7-17
	Sky	62	57-67
	Cloud	66	61-71
Olive	Tree Line	10	5-15
	Grass	22	17-27
	Earth	9	4-14
	Sky	96	91-101
	Cloud	83	78-88
Dark Green	Tree Line	33	28-38
	Grass	42	37-47
	Earth	42	37-47

Target	Background	Recommended ΔE^{*}_{uv}	Recommended Range
Green Camouflage Surface Vehicle (CONT'D)			
	Sky	68	63-73
	Cloud	65	60-70
Medium Green	Tree Line	31	26-36
	Grass	34	29-39
	Earth	32	27-37
	Sky	79	74-84
	Cloud	65	60-70
Light Green	Tree Line	32	27-37
	Grass	22	17-27
	Earth	29	24-34
	Sky	64	59-69
	Cloud	66	61-71
Greenish Brown	Tree Line	14	9-19
	Grass	19	14-24
	Earth	10	5-15
	Sky	64	59-69
	Cloud	65	60-70
Tan	Tree Line	18	13-23
	Grass	22	17-27
	Earth	9	4-14
	Sky	39	34-44
Brown	Cloud	44	39-49
	Tree Line	7	2-12
	Grass	17	12-22
	Earth	9	4-14

Green Camouflage Surface Vehicle Color Schemes:

Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
Light Green	Light Green	Light Green	n/a	Green
Med. Green	Med. Green	Dark Green		Olive
Brown	Dark Green			Tan
				Greenish Brown

Target	Background	Recommended ΔE^*_{uv}	Recommended Range
Desert Monochrome Surface Vehicle	Sky	65	60-70
Desert Monochrome Surface Vehicle	Cloud	51	46-56
Desert Monochrome Surface Vehicle	Tree Line	28	23-33
Desert Monochrome Surface Vehicle	Grass	22	17-27
Desert Monochrome Surface Vehicle	Earth	18	13-23
Desert Camouflage Surface Vehicle			
Desert	Sky	85	80-90
	Cloud	73	68-78
	Tree Line	34	29-39
	Grass	33	28-38
	Earth	24	19-29
Tan	Sky	62	57-67
	Cloud	60	55-65
	Tree Line	26	21-31
	Grass	22	17-27
	Earth	19	14-24
Light Tan	Sky	91	86-96
	Cloud	70	65-75
	Tree Line	18	13-23
	Grass	22	17-27
	Earth	16	11-21
Dark Tan	Sky	90	85-95
	Cloud	77	72-82
	Tree Line	9	4-14
	Grass	30	25-35
	Earth	25	20-30
Brown	Sky	62	57-67
	Cloud	62	57-67
	Tree Line	20	15-25
	Grass	21	16-26
	Earth	11	6-16

Target	Background	Recommended ΔE^*_{uv}	Recommended Range
Desert Camouflage Surface Vehicle (CONT'D)			
	Sky	63	58-68
	Cloud	62	57-67
Greenish Brown	Tree Line	25	20-30
	Grass	22	17-27
	Earth	17	12-22
	Sky	101	96-106
	Cloud	84	79-89
Olive	Tree Line	47	42-52
	Grass	47	42-52
	Earth	40	35-45
	Sky	94	89-99
	Cloud	92	87-97
Black	Tree Line	14	9-19
	Grass	48	43-53
	Earth	41	36-46

Desert Camouflage Surface Vehicle Color Schemes:

Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
n/a	Desert Olive	Light Tan Dark Tan Black	n/a	Desert Tan Brown Greenish Brown

Green Monochrome Air Vehicle	Sky	68	63-73
Green Monochrome Air Vehicle	Cloud	64	59-69
Green Monochrome Air Vehicle	Tree Line	14	9-19
Green Monochrome Air Vehicle	Grass	15	10-20
Green Monochrome Air Vehicle	Earth	19	14-24
Green Monochrome Air Vehicle	Water	39	34-44
Green Monochrome Air Vehicle	Ocean	48	43-53

Target	Background	Recommended ΔE^*_{uv}	Recommended Range
Green Camouflage Air Vehicle			
	Sky	66	61-71
	Cloud	65	60-70
Green	Tree Line	20	15-25
	Grass	15	10-20
	Earth	19	13-23
	Water	64	59-69
	Ocean	39	34-44
	Sky	100	95-105
	Cloud	79	74-84
Light Green	Tree Line	30	25-35
	Grass	27	22-32
	Earth	31	26-36
	Water	25	20-30
	Ocean	53	48-58
	Sky	65	60-70
	Cloud	63	58-68
Medium Green	Tree Line	5	0-10
	Grass	25	20-30
	Earth	22	17-27
	Water	29	24-34
	Ocean	30	25-35
	Sky	99	94-104
	Cloud	92	87-97
Dark Green	Tree Line	34	29-39
	Grass	51	46-56
	Earth	47	42-52
	Water	28	23-33
	Ocean	55	50-60

Target	Background	Recommended ΔE^{*}_{uv}	Recommended Range
Green Camouflage Air Vehicle (CONT'D)			
	Sky	63	58-68
	Cloud	66	61-71
Olive	Tree Line	11	6-16
	Grass	18	13-23
	Earth	10	5-15
	Water	58	53-63
	Ocean	32	27-37
	Sky	64	59-69
	Cloud	67	62-72
Brownish Green	Tree Line	13	8-18
	Grass	21	16-26
	Earth	8	3-13
	Water	58	53-63
	Ocean	32	27-37
	Sky	39	34-44
Brown	Cloud	44	39-49
	Tree Line	7	2-12
	Grass	16	11-21
	Earth	8	3-13
	Water	n/a [2]	n/a
	Ocean	n/a	n/a
	Sky	35	30-40
Dark Gray	Cloud	46	41-51
	Tree Line	8	3-13
	Grass	24	19-29
	Earth	17	12-22
	Water	n/a	n/a
	Ocean	n/a	n/a

Green Camouflage Air Vehicle Color Schemes:

Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
Brown	Light Green	Light Green	n/a	Green
Med. Green	Dark Green	Med. Green		Olive
Dark Gray		Dark Green		Brownish Green

Target	Background	Recommended ΔE^{*}_{uv}	Recommended Range
Desert Monochrome Air Vehicle	Sky	65	60-70
Desert Monochrome Air Vehicle	Cloud	52	47-57
Desert Monochrome Air Vehicle	Tree Line	28	23-33
Desert Monochrome Air Vehicle	Grass	24	19-29
Desert Monochrome Air Vehicle	Earth	18	13-23
Desert Monochrome Air Vehicle	Water	43	38-48
Desert Monochrome Air Vehicle	Ocean	47	42-52
Desert Camouflage Air Vehicle			
	Sky	85	80-90
	Cloud	70	65-75
Desert	Tree Line	29	24-34
	Grass	26	21-31
	Earth	19	14-24
	Water	57	52-62
	Ocean	60	55-65
	Sky	110	105-115
	Cloud	69	64-74
Light Tan	Tree Line	51	46-56
	Grass	29	24-34
	Earth	19	14-24
	Water	54	49-59
	Ocean	58	53-63
	Sky	77	72-82
	Cloud	63	58-68
Medium Tan	Tree Line	22	17-27
	Grass	17	12-22
	Earth	11	6-16
	Water	45	40-50
	Ocean	34	29-39

Target	Background	Recommended ΔE^*_{uv}	Recommended Range
Desert Camouflage Air Vehicle (CONT'D)			
	Sky	55	50-60
	Cloud	56	51-61
Dark Tan	Tree Line	16	11-21
	Grass	17	12-22
	Earth	9	4-14
	Water	53	48-58
	Ocean	28	23-33
	Sky	100	95-105
	Cloud	77	72-82
Greenish	Tree Line	32	27-37
	Grass	32	27-37
	Earth	21	16-26
	Water	29	24-34
	Ocean	71	66-76
	Sky	94	89-99
	Cloud	89	84-94
Black	Tree Line	10	5-15
	Grass	44	39-49
	Earth	38	33-43
	Water	32	27-37
	Ocean	33	28-38

Desert Camouflage Air Vehicle Color Schemes:

Sample #1	Sample #2	Sample #3	Sample #4	Sample #5
n/a	Desert Light Light Green	Tan Med. Tan Black	n/a	Desert Med. Tan Dark Tan

Target	Background	Recommended ΔE^{*}_{uv}	Recommended Range
Grey Monochrome Air Vehicle	Sky	60	55-65
Grey Monochrome Air Vehicle	Cloud	50	45-55
Grey Monochrome Air Vehicle	Tree Line	37	32-42
Grey Monochrome Air Vehicle	Grass	40	35-45
Grey Monochrome Air Vehicle	Earth	42	37-47
Grey Monochrome Air Vehicle	Water	40	35-45
Grey Monochrome Air Vehicle	Ocean	46	41-51
Blue Monochrome Air Vehicle	Sky	41	36-46
Blue Monochrome Air Vehicle	Cloud	28	23-33
Blue Monochrome Air Vehicle	Tree Line	87	82-92
Blue Monochrome Air Vehicle	Grass	80	75-85
Blue Monochrome Air Vehicle	Earth	85	80-90
Blue Monochrome Air Vehicle	Water	67	62-72
Blue Monochrome Air Vehicle	Ocean	41	36-46
Black Monochrome Air Vehicle	Sky	66	61-71
Black Monochrome Air Vehicle	Cloud	67	62-72
Black Monochrome Air Vehicle	Tree Line	34	29-39
Black Monochrome Air Vehicle	Grass	43	38-48
Black Monochrome Air Vehicle	Earth	39	34-44
Black Monochrome Air Vehicle	Water	18	13-23
Black Monochrome Air Vehicle	Ocean	63	58-68
Grey Monochrome Surface Ship	Sky	57	52-62
Grey Monochrome Surface Ship	Cloud	39	34-44
Grey Monochrome Surface Ship	Tree Line	43	38-48
Grey Monochrome Surface Ship	Grass	39	34-44
Grey Monochrome Surface Ship	Earth	39	34-44
Grey Monochrome Surface Ship	Water	29	24-34
Grey Monochrome Surface Ship	Ocean	25	20-30

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1 The camouflage colors listed are the subjective labels given to the rendered color that was observed.

2 n/a - indicates a target/background combination was not available for measurement.

5.1.2.2 Non-Visual Electromagnetic (TBD)
5.1.2.3 Acoustic (TBD)
5.1.2.4 Time (TBD)
5.1.2.5 Other Mediums (TBD)

5.2 <u>Battlespace and Environment Entity Description</u> (TBD)

5.2.1 Communication (TBD)
5.2.2 Sensors (TBD)
5.2.3 Movement (TBD)
5.2.4 Appearance (TBD)
5.2.5 Weapons/Capability (TBD)
5.2.6 Vulnerability (TBD)
5.2.7 Consumables (TBD)
5.2.8 Behaviors (ROE) (TBD)
5.2.9 C^2I (TBD)
5.2.10 Mechanical Countermeasures & Counter-Countermeasures (TBD)
5.2.11 Warfighter Interface (TBD)

5.2.11.1 Controls (TBD)
5.2.11.2 Displays (TBD)

5.2.12 Logistics and Maintenance Interface (TBD)
5.2.13 Electronic Warfare (TBD)

5.2.13.1 ECM (TBD)
5.2.13.2 ECCM (TBD)
5.2.13.3 ESM (TBD)

5.2.14 Combat ID/IFFN (TBD)
5.2.15 Navigation (TBD)
5.2.16 Fire Control and Targeting Systems (TBD)
5.2.17 Reliability and Availability (TBD)

5.3 <u>Technical Description</u> (TBD)

5.3.1 Network Description (TBD)

5.3.1.1 Throughput Performance (TBD)
5.3.1.2 Connection Type (TBD)
5.3.1.3 Network Delay (TBD)
5.3.1.4 Clocks (TBD)

5.3.1.4.1 Start Time (TBD)
5.3.1.4.2 Synchronization Resolution (TBD)

5.3.1.5 Security (TBD)
5.3.1.6 Data Recorder (TBD)
5.3.1.7 Processing Workload (TBD)
5.3.1.8 Interaction Delay (TBD)

5.3.2 User Description (TBD)

5.3.2.1 Non-Traditional Controls and Displays (TBD)

5.3.2.1.1 Target Augmentation (TBD)

In DIS exercises, the majority of out-the-window displays have insufficient resolution to display a target that can be detected, recognized and identified at the ranges possible in the real world (see Table 3). When targets cannot be portrayed realistically at the required range, target augmentation shall be used to assist the exercise participant in detection, recognition and identification of the target. The method of augmentation is left to the implementer. When the target reaches a range at which the target can be detected, recognized or identified with the resolution of the display, the augmentation shall be smoothly and gradually removed.

Table 3
Name/Range

Target Type	Detection	Recognition	Identification by quarter
(TBD)			

5.3.2.2 Embedded Features (TBD)
5.3.2.3 User Workload (TBD)
5.3.2.4 Data Recorder (TBD)

5.4 Scenario Management Description (TBD)

5.4.1 Non-Representational C^4I (TBD)
5.4.2 Doctrinal (ROE) (TBD)
5.4.3 Geopolitics (TBD)
5.4.4 Non-Representational Threats (TBD)

6.1 Introduction

DIS will take advantage of currently installed and future simulations manufactured by different organizations. Consequently, a means must be found for assuring interoperability between dissimilar simulations. The first step in achieving this interoperability is to develop a set of standards to address:

- Protocol Data Units
- Communication Architecture
- Fidelity Correlation
- Exercise Control and Feedback

The current work on standards began in August 1989 with the first workshop on Standards for the Interoperability of Defense Simulations. Five subsequent workshops were held at six month intervals. As a result of these workshops and subsequent subgroup meetings, over 150 position papers containing recommendations for the standards were submitted to the Institute for Simulation and Training (IST). Using the work of SIMNET as a baseline and considering recommendations made in meetings and position papers, IST is developing draft standards which address the topic areas listed above.

6.2 Description of Distributed Interactive Simulation

The basic concepts of Distributed Interactive Simulation (DIS) are an extension of the Simulation Networking (SIMNET) program developed by the Defense Advanced Research Projects Agency (DARPA). The purpose of DIS is to allow dissimilar simulators distributed over a large geographical area to interact in a team environment. These simulators communicate over local area networks and wide area networks. The basic DIS concepts are:

- No central computer for event scheduling or conflict resolution

- Autonomous simulation nodes responsible for maintaining the state of one or more simulation entities

- There is a standard protocol for communicating "ground truth" data

- Receiving nodes are responsible for determining what is perceived

- Simulation nodes communicate only changes in their state

- Dead reckoning is used to reduce communications processing

6.3 Intended Use

The primary mission of DIS is to create synthetic, virtual representations of warfare environments by systematically connecting separate elements or subcomponents of simulation which reside at distributed, multiple locations. DIS can be used as a substitute for some field training and testing, and can allow for practice of warfighting skills when cost, safety, environmental and political constraints will not permit the field training and testing required to maintain readiness.

The property of connecting separate sub-components or elements affords the capability to configure a wide range of simulated warfare representations patterned after the task force organization of actual units, both friendly and opposing, including joint and combined force operations to represent a wide range of warfighting missions facing U.S. forces today and in the future. Equally important is the property of interoperability which allows different simulation environments to efficiently and consistently interchange data elements essential to representing warfighting interactions and outcomes.

In effect, interoperable simulations will exchange data in a manner such that the differences in the representation of the simulated battlefield will be transparent or "seamless" as experienced by participants interacting with their particular representation of the warfighting environment. This property affords the opportunity for linking heterogeneous representations, each providing a locally consistent simulated environment, through use of buffers or translators to create a seamless interconnection. With these properties, it is possible to have simulation components which meet special purpose local uses and when required can link together to form larger scale warfighting environment representations.

In addition to DIS's primary mission of supporting training and testing needs, DIS can serve as a tool for mission planning and mission rehearsal.

6.4 Operational Scenarios

6.4.1 DIS Training Exercise Scenarios

The primary customers for DIS training exercises are commanders, from unit commanders to Commanders In Chief (CINCs). Unit commanders who wish to conduct a training exercise involving only their unit will coordinate with other unit commanders at that base, schedule time for their personnel on the simulators and conduct the exercise using the simulation resources attached to the Local Area Network (LAN) at the base. If the unit commander requires outside support in the form of an opposing force (OPFOR) or additional friendly forces, the commander will follow the procedure discussed below for CINCs.

CINCs will use the wide area network WAN services of DIS. The CINC will specify the mission objective (liberate country green) and the CINC's staff will plan the exercise in the same manner as an actual mission. Once the staff has determined which forces will be required to conduct the exercise, they will contact the commanders of these forces through normal channels. In addition, they will contact the DIS Administrative Unit to determine the availability of (1) simulators at those forces' bases; and (2) bandwidth on DIS. DIS is being designed such that a number of separate exercises can be conducted simultaneously on the WAN in a way that is transparent to the participants. The DIS administrative unit will assign a unique exercise number to differentiate it from other simultaneous exercises. It will also calculate the required bandwidth for the required simulators as well as that required for the exercises already scheduled during the desired time period. If the available bandwidth is exceeded, the administrative unit will resolve the conflicts with rescheduling acceptable to all participants. Once this scheduling is complete, all participants will complete their planning for the exercises.

As the planning continues, the CINC will hold video conferences (over the DIS WAN) with the unit commanders to simulate actual planning meetings. As the mission start day approaches, the Operations Officer will issue orders to the unit commanders for initial deployment of forces. These unit commanders will determine the deployment of their forces and give the initial locations to the local DIS exercise controllers to feed into the simulators.

As the day of exercise start arrives, the local commanders and their staffs will assemble in the DIS LAN controller's room to participate in a video conference final briefing with the CINC. At the mission start time, the DIS WAN will issue a start command to each location and the LAN controllers will issue start commands to the simulators. The other threats and friendlies will then begin to appear on each simulator's displays. Radio communications will be digitized and sent in packets over the DIS network to the appropriate simulators and replayed if the receiving simulator is in range and on the same frequency. As the battle proceeds and each side takes losses, the LAN controllers may be allowed to reconstitute forces to simulate replacements and to allow participants to continue training. During the battle, the debrief station at each location will store all forces location and status messages (protocol data units) for later replay.

When the CINC has achieved his goal, he will issue a Cease Fire command and the DIS LAN controllers will issue a freeze command to all simulators. After participants have gathered in each DIS LAN controller's room, the CINC will conduct a video conference debrief of the exercise. During this debrief, the WAN manager will issue commands to each LAN exercise feedback device to replay the exercise. The CINC will have the controller start, stop and reverse the playback as required to illustrate the lessons learned during the exercise. If desired, the debrief will be broken into segments such as maneuver, logistics, etc. and the LAN controller will enter a command for the debrief station to display only the desired forces.

Once the CINC's debrief is completed, the unit commanders will call in lower ranking personnel for a debriefing. During this debriefing, the LAN controllers will play back the exercise but will concentrate the debrief view on the area of responsibility for that unit. After completion of the exercise debriefs, the stored forces location and status messages will be permanently stored for use in future classroom demonstrations or analysis efforts.

6.4.2 DIS Decision Support Scenarios

The primary customers for DIS decision support exercises are the Combat Development, System Acquisition, Test and Evaluation and Training communities. If the test organization has sufficient simulations of threat and friendly forces at the test facility, they will schedule time for their personnel on the simulators and conduct the exercise using the simulation resources attached to the LAN at the test facility. If the test organization requires outside support in the form of an OPFOR or additional friendly forces, the commander will follow the procedure discussed below.

Tests that require outside simulation resources will use the wide area network (WAN) services of DIS. The test organization will specify the test objectives (determine system improvement's effect on outcome of realistic battle engagement) and the test director's staff will plan the exercise. Once the staff has determined which forces will be required to conduct the exercise, they will contact the DIS administrative unit to determine (1) the availability of the simulated/actual equipment/personnel at other locations; and (2) bandwidth on DIS. DIS is being designed such that a number of separate exercises can be conducted simultaneously on the WAN in a way that is transparent to the participants. The administrative unit will assign a unique exercise number to differentiate it from other simultaneous exercises. It will also calculate the required bandwidth for the required simulators as well as that required for the exercises already scheduled during the desired time period. If the available bandwidth is exceeded, the administrative unit will resolve the conflicts with rescheduling acceptable to all participants.

Once this scheduling is complete, all participants will complete their planning for the exercises. As the planning continues, the test director may hold video conferences (over the DIS WAN) with the participants to iron out procedures.

As the day of exercise start arrives, the distributed participants will assemble in the DIS LAN controller's room to participate in a video conference final briefing with the Test Director. At the exercise start time, the DIS WAN will issue a start command to each location and the LAN controllers will issue start commands to the simulators/actual equipment. The other threats and friendlies will then begin to appear on each simulator's/actual equipment's displays. Radio communications will be digitized and sent in packets over the DIS network to the appropriate simulators/actual equipment and replayed if the receiving entity is in range and on the same frequency. As the exercise proceeds and each side takes losses, the LAN controllers may be allowed to reconstitute forces to simulate replacements and to allow participants to continue provide additional threats and friendlies. During the exercise, the debrief station at each location will store all forces location and status messages (protocol data units) for later replay.

When the exercise is complete, the Test Director will issue a stop command and the DIS LAN controllers will issue a freeze command to all simulators/actual equipment. After participants have gathered in each DIS LAN controller's room, the Test Director will conduct a video conference debrief of the exercise. During this debrief, the WAN manager will issue commands to each LAN exercise feedback device to replay the exercise. The Test Director will have the controller start, stop and reverse the playback as required to illustrate the lessons learned during the test exercise. If desired, the debrief will be broken into segments such as maneuvers, electronic warfare, etc. and the LAN controller will enter a command for the debrief station to display only the desired forces. After completion of the exercise debriefs, the stored forces location and status messages will be permanently stored for use in future demonstrations or analysis efforts.

7.0 REFERENCES

International Organization of Standardization (ISO) (1991). ISO Draft Standard 9241: Ergonomics requirements for office work with visual display terminals (VDTs). Washington, DC: ISO.

Thorrell, L.G., & Smith, W.J. (1990). Using computer color effectively. Englewood Cliffs, NJ: Prentice Hall.

APPENDICES

Appendix A
Target/Background Contrast Ratio Metric: Calculation of ΔE^*_{uv}

BACKGROUND

The new International Organization for Standardization (ISO) draft standard for video displays recommends the use of the CIELUV and the ΔE^*_{uv} metric for assessing the discriminability of pairs of colored stimuli (ISO, 1991; Thorrell & Smith, 1990). It is recognized by the ISO Committee that the discriminability of pairs of colors depends on both differences in chromaticity and luminance. The color difference equation is expressed:

$$\Delta E^*_{uv}=[(\Delta L^*)^2+(\Delta u^*)^2+(\Delta v^*)^2]^{1/2}$$

Where:

L^* (luminance factor) $= 116(Y/Y_n)^{1/3}-16$

Y is the luminance or brightness value usually measured in cd/m^2, and Y_n is that of a specified white object-color stimulus (usually 100, but often based upon the maximum white stimulus that an image generator/monitor could display). The L^* equation above is valid when $Y/Y_n > 0.008856$. When Y/Y_n is less than or equal to 0.008856, then the L^* equation is expressed as: $L^* = 903.3(Y/Y_n)$

$u^* = 13L^*(u'-u_n)$

Where: $u' = 4x/(-2x+12y+3)$
$u_n = .198$

$v^* = 13L^*(v'-v_n)$

Where: $v' = 9y/(-2x+12y+3)$
$v_n = .468$

In order to calculate ΔE^*_{uv} from the equation above, the user need only provide the x,y, and Y values. The x and y values represent a color's hue and saturation, and Y represents its luminance. These values can be obtained by using a standard chroma meter (e.g., Minolta CS-100). From the original x,y, and Y values, L^*, u^*, and v^* values are calculated using the equations above (some chroma meters provide L^*, u^*, and v^* values without having to perform any additional calculations). In either case, with the x, y, and Y values, the above mathematical transformations can be made to arrive at ΔE^*_{uv}.

Appendix B

MEAN AND RANGE CHROMATICITY (x,y) AND LUMINANCE (Y) VALUES FOR TARGETS[3]

Target		x (range)	y (range)	Y (range)[4]
Green Monochrome Surface Vehicle		.33 (.29-.36)	.44 (.38-.49)	27.94 (2.23-111.00)
Green Camouflage [5] Surface Vehicle				
	Green	.40 (.40)	.49 (.49)	2.05 (2.05)
	Olive	.39 (.39)	.47 (.47)	1.17 (1.17)
	Dark Green	.32 (.28-.37)	.44 (.44-.44)	3.60 (1.55-5.64)
	Medium Green	.33 (.29-.37)	.39 (.34-.45)	5.39 (1.96-8.82)
	Light Green	.32 (.29-.37)	.43 (.37-.47)	9.65 (1.89-15.85)
	Greenish Brown	.41 (.41)	.49 (.49)	1.71 (1.71)
	Tan	.42 (.42)	.46 (.46)	2.02 (2.02)
	Brown	.31 (.31)	.34 (.34)	7.43 (7.43)
Desert Monochrome Surface Vehicle		.35 (.33-.37)	.38 (.36-.40)	17.58 (6.70-24.50)
Desert Camouflage Surface Vehicle				
	Desert	.41 (.40-.41)	.42 (.41-.43)	5.73 (3.37-8.09)
	Tan	.40 (.40)	.43 (.43)	4.07 (4.07)
	Light Tan	.32 (.32)	.41 (.41)	11.40 (11.40)
	Dark Tan	.31 (.31)	.41 (.41)	5.98 (5.98)
	Brown	.40 (.40)	.44 (.44)	2.70 (2.70)
	Greenish Brown	.40 (.40)	.43 (.43)	3.67 (3.67)
	Olive	.39 (.39)	.41 (.41)	4.63 (4.63)
	Black	.32 (.32)	.41 (.41)	1.25 (1.25)
Green Monochrome Air Vehicle		.33 (.29-.35)	.44 (.41-.46)	6.51 (1.46-9.84)
Green Camouflage Air Vehicle				
	Green	.40 (.40)	.49 (.49)	2.85 (2.85)
	Light Green	.33 (.30-.37)	.48 (.48-.49)	6.85 (4.31-9.39)
	Medium Green	.29 (.29-.29)	.41 (.34-.48)	5.85 (2.74-8.97)
	Dark Green	.37 (.36-.37)	.46 (.43-.48)	1.42 (.87-1.97)
	Olive	.40 (.40)	.49 (.49)	1.65 (1.65)
	Brownish Green	.41 (.41)	.48 (.48)	1.41 (1.41)

Target	x (range)	y (range)	Y (range)
Green Camouflage Air Vehicle (CONT'D)			
Brown	.31 (.31)	.34 (.34)	7.79 (7.79)
Dark Gray	.29 (.29)	.31 (.31)	5.65 (5.65)
Desert Monochrome Air Vehicle	.34 (.31-.38)	.38 (.37-.40)	19.08 (4.75-27.20)
Desert Camouflage Air Vehicle			
Desert	.38 (.36-.39)	.41 (.41-.42)	17.72 (4.59-30.85)
Light Tan	.37 (.37)	.44 (.44)	36.50 (36.50)
Medium Tan	.36 (.35-.37)	.43 (.42-.44)	8.88 (3.80-13.95)
Dark Tan	.37 (.37)	.41 (.41)	3.12 (3.12)
Greenish	.37 (.37)	.41 (.41)	12.95 (12.95)
Black	.31 (.31)	.43 (.43)	1.67 (1.67)
Gray Monochrome Air Vehicle	.30 (.28-.34)	.37 (.31-.46)	30.36 (.60-122.50)
Blue Monochrome Air Vehicle	.24 (.22-.26)	.29 (.27-.31)	75.40 (40.80-110.00)
Black Monochrome Air Vehicle	.30 (.29-.30)	.33 (.31-.34)	2.97 (1.78-4.15)
Gray Monochrome Surface Ship	.29 (.28-.30)	.32 (.30-.36)	29.71 (13.00-57.75)

[3] These mean values were compiled from an independent survey of five image generator manufacturers whose equipment is DIS-compatible.

[4] Luminance (Y) is measured in nits (cd/m^2)

[5] The camouflage colors listed for a given target represent all camouflage colors observed across all IGs sampled.

Appendix C

MEAN AND RANGE CHROMATICITY (x,y) AND LUMINANCE (Y) VALUES FOR BACKGROUNDS[6]

Background	x	(range)	y	(range)	Y	(range)[7]
Sky	.24	(.22-.28)	.27	(.23-.29)	59.96	(10.5-60.3)
Cloud	.28	(.27-.29)	.31	(.31-.33)	87.52	(16.4-162)
Tree Line	.32	(.27-.36)	.45	(.35-.54)	2.74	(1.74-5.31)
Grass	.33	(.30-.37)	.44	(.40-.46)	13.23	(3.6-24.3)
Earth	.37	(.33-.41)	.42	(.37-.48)	14.21	(1.94-33.85)
Water	.24	(.18-.30)	.28	(.15-.32)	7.34	(4.4-14.2)
Ocean	.25	(.23-.29)	.29	(.26-.33)	16.00	(2.9-27.3)

[6] These mean values were compiled from an independent survey of five image generator manufacturers whose equipment is DIS-compatible.

[7] z (luminance) is measured in nits (cd/m^2)

Appendix D

LINE-OF-SIGHT-INTERVISIBILITY METRIC: SAMPLING APPROACH AND CALCULATIONS

The objective of the line-of-sight intervisibility metric is to estimate the probability that two data bases agree on line of sight intervisibility given a randomly select pair consisting of an observer and a target.

As an illustration, consider pairs of randomly selected sites (x_{1a},y_{1a}), (x_{1b},y_{1b}), ..., (x_{ka},y_{ka}),(x_{kb},y_{kb}). We will imagine for now that site a is the observer and site b the target. Each pair of sites is then compared for line of sight using both data bases. It will be convenient to summarize the results in a table, as follows:

		Data Base II		
		Sees	Doesn't See	
Data Base I	Sees	n_{11}	n_{12}	r_1
	Doesn't See	n_{21}	n_{22}	r_2
		c_1	c_2	n

The notation is intended to be suggestive: for n_{ij}, the i represents the row of the table, the j represents the column; r_i represents the sum of entries in "row i"; c_j represents the sum of entries in "column j"; n is the total number of line of sight checks.

If the data bases agree perfectly on the n test cases, then $n_{21} = n_{21} = 0$ and $n_{11} + n_{22} = n$. For partial agreement, the quantity $(n_{11}+n_{22})/n$ estimates the proportion of agreement of the two data bases. This proportion may be a suitable metric for comparing data bases. Qualitatively, it has similar properties of the correlation coefficient, but not it's inherent flaws.

There does exist, however, one potential area of concern. Namely, this formulation inherently presumes that agreement with both data bases providing line of sight and agreement with both data bases indicating no line of sight are of comparable merit. Perhaps it is critical in some application, that if one data base reports line of sight, the other ought to as well. The quantity

$n_{11}/(n_{11}+n_{21}+n_{12})$ estimates the proportion of cases that the two data bases agree on line of sight, given that one data base has indicated that line of sight exists. A similar expression, namely, $n_{22}/(n_{22}+n_{21}+n_{12})$ estimates the proportion of cases that the two data bases agree on the absence of line of sight, given that one data base has indicated this absence.

To develop a scheme for determining the sample size in estimating the various proportions, a binomial model is proposed. In this model, the test cases should be independent (one outcome does not influence other outcomes) and the outcome has a constant success probability. The selection of pairs of sites using a uniform distribution over the region will insure the critical independence condition.

Sample size considerations. An obvious question is how many pairs of observer-target points must be sampled to accurately estimate the proportion of agreement between the two data bases? Letting this proportion be denoted p, we would hope that it is close to 1 which represents perfect data base agreement. Of course, we do not know the population proportion, so we must estimate it with $\hat{p}$, the sample proportion as given above. For fairly large samples ("large" will be defined shortly), $\hat{p}$ will follow an approximate normal distribution. In particular, n larger than $9p/(1-p)$ will suffice. Taking a fairly extreme value of p, say 0.99, yields $n = 891$. For convenience in converting between counts and relative frequencies, $n=1000$ is recommended. For a true p less than 0.99, 1000 pairs will insure that our approximation procedure is valid.

Sample results. For illustration, suppose that 1000 samples of pairs of points are generated and line of sight determined. The sample proportion of agreement $\hat{p}$ gives a natural estimate of p. How well do we know this quantity? A confidence interval provides an answer. The $100(1-\alpha)\%$ confidence interval for p is given by:

$$\hat{p}\pm z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

Suppose we observe $\hat{p} = .80$; a 95% confidence interval is (0.775, 0.825). With this type of calculation, we would expect that about 95% of similarly constructed intervals (based on new samples) would contain the true proportion of agreement p.

Another potential use of this statistical methodology is to test the sample proportion against a standard value, such as 0.90 which you have suggested. A one-sided test is appropriate, as follows:

$$H_0:\ p = p_0 \quad \text{vs.} \quad H_A:\ p < p_0$$

The value p_0 is the standard value for agreement (perhaps 0.90). Sample proportions above p_0 offer no problems. For those below the prescribed value, are they sufficiently lower so that mere chance does not account for them? The testing procedure is straightforward:

1. Compute $z = \dfrac{\hat{p} - p_0}{\sqrt{\dfrac{p_0(1-p_0)}{n}}}$.

2. If $z < -z_\alpha$, then reject the null hypothesis H_0 in favor of the alternative hypothesis H_A.

The value z_α is obtained from a standard normal table (e.g., $z_{.05} = 1.645$). As an example, suppose $\hat{p} = 0.86$. We calculate $z = (0.86\text{-}0.90)/\surd[0.9\cdot 0.1]/1000 = -4.21$. Since the condition $-4.21 < -1.645$, we would reject H_0 and conclude that the differences in the data bases are real and not due to chance variation.